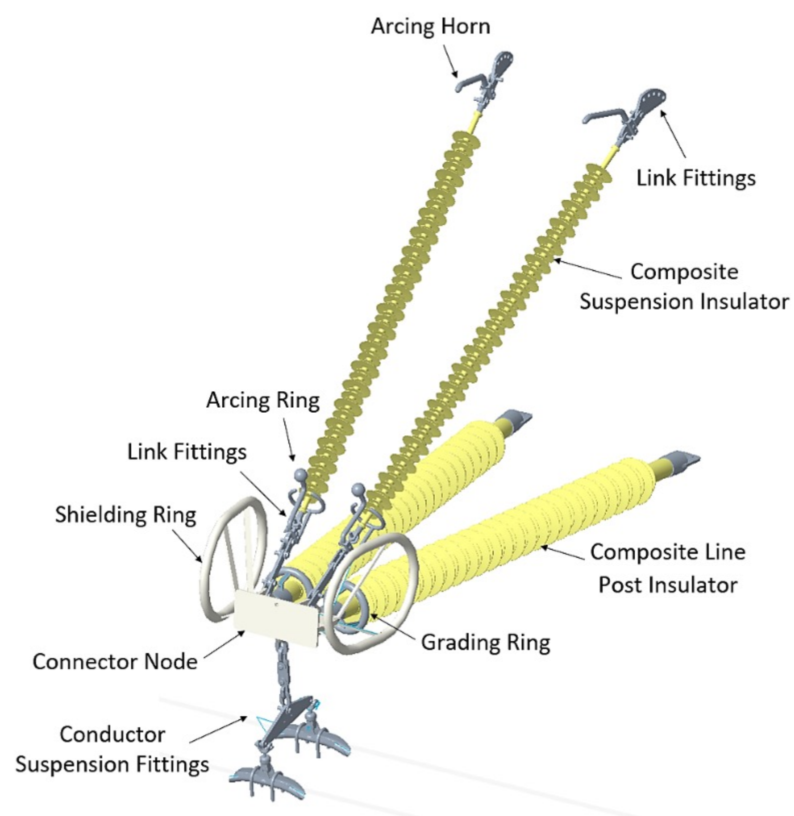
Electric Field Grading Design and Validation Tests of Composite Insulated Cross-arm (CICA)

Introduction

- Composite insulated cross-arm (CICA)
  - High strength BLP version of the well-known braced line posts (BLP)
  - High strength means longer line spans and more optimized designs
- Assembly Types
  - Tri-Pod
  - Double V
- Tower Applications
  - Monopole
  - Lattice
- Core Rod Optimization
  - 2.5” to 10”
- Core Rod Types
  - Solid Core or Hollow core
-



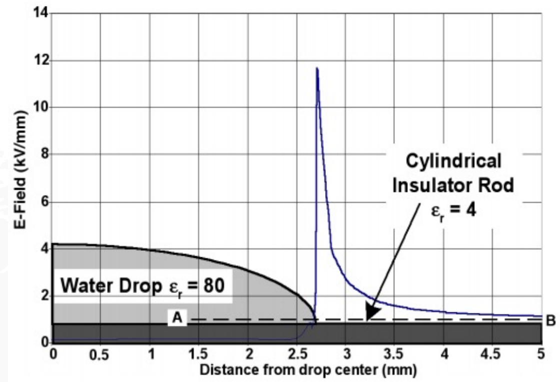
Double Vee CICA

Hydrophobicity and Electric Fields

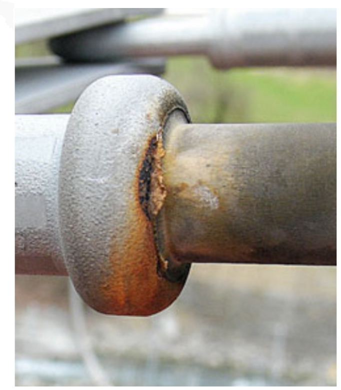
- **<u>Hydrophobicity</u>**
  - Key property for long term operation
  - Causes water droplets to ‘bead’ on the insulator housing and enhances E-field magnitude under wet conditions

- **<u>Water droplet induced corona (WDIC)</u>**
  - Recognized ageing mechanism
  - Long term WDIC = loss of hydrophobicity and housing/seal damage

- **<u>EPRI recommended E-field on housing</u>**
  - < 4.2 kV/cm (420V/mm)



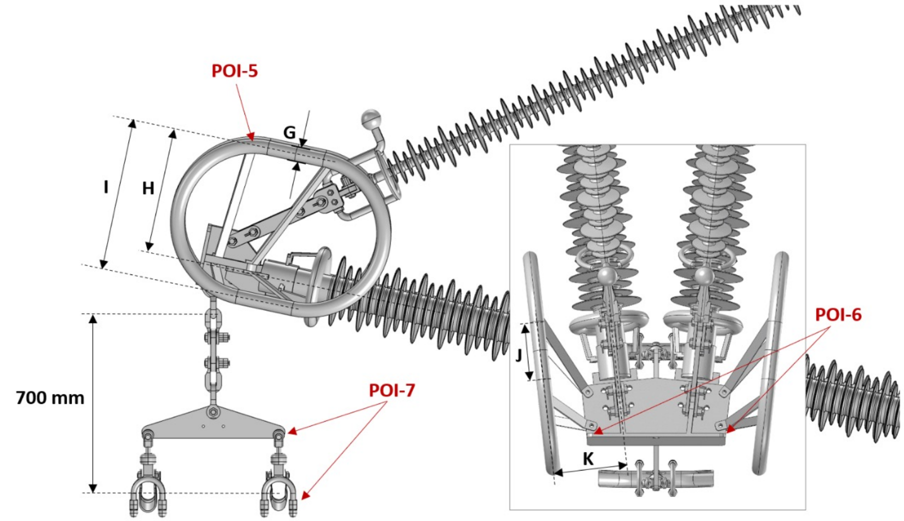
Effect of water droplet on E-field enhancement (Ref: EPRI Red Book)



Damage caused by WDIC (Ref: Silicon Composite Insulators Book)

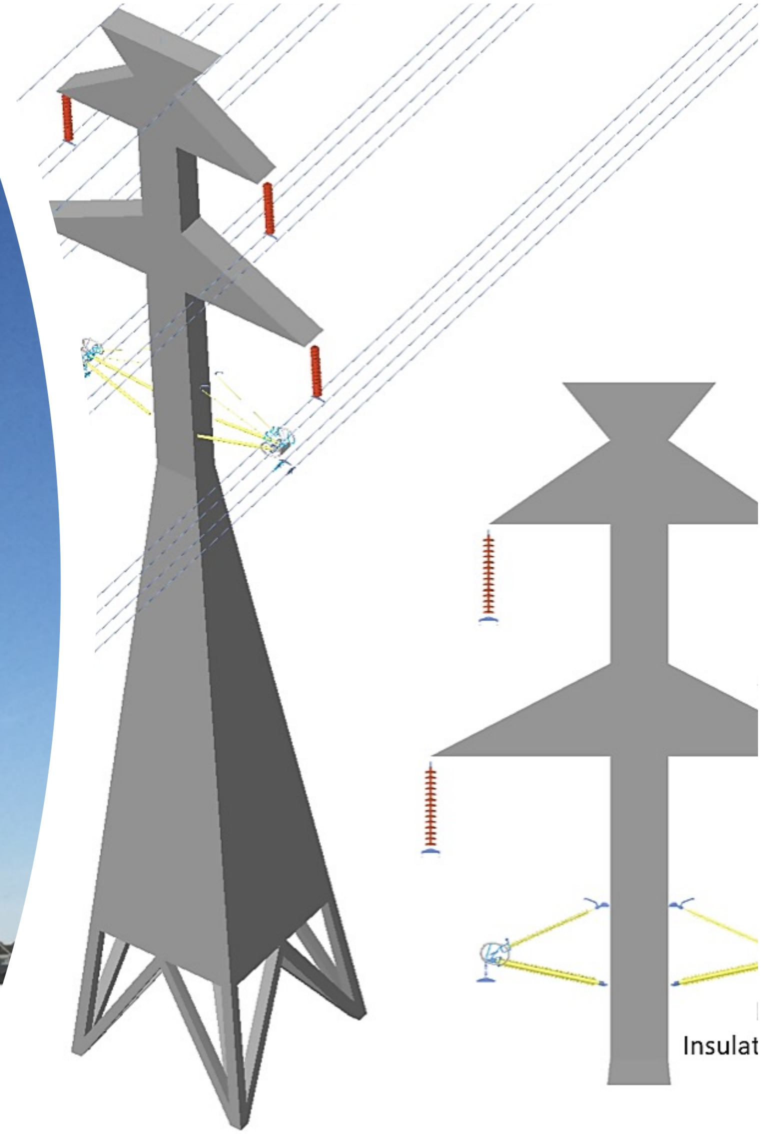
Electric Field Grading on CICA

- Composite insulated cross-arm (CICA)
  - Compact lines produce higher E-field stresses presenting some additional and unique challenges
  - Need Tailored or bespoke grading device designs
  - More points of interests (POI) where the electric field needs to be analyzed and concurrently graded



Case Study

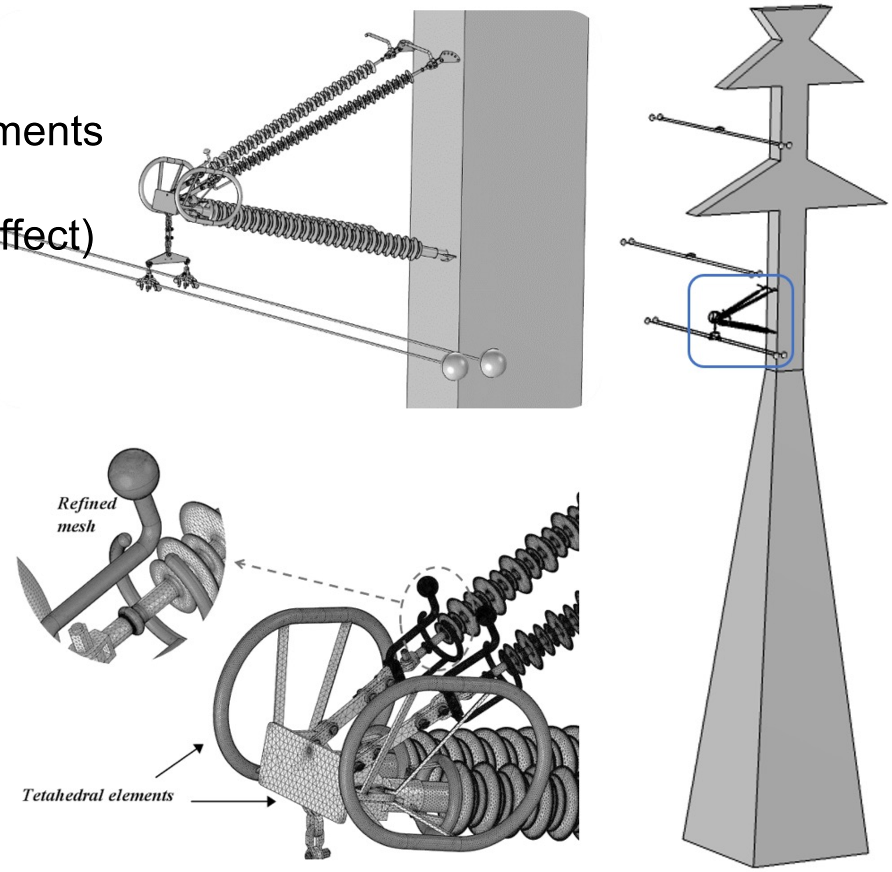
- Bottom phases of 230 kV lattice tower retrofitted with CICA for ground clearance improvement
- Standard BLP could not full-fill load requirements
- Cost effective solution
- Increase the ground clearance by up to 2.2m without the need of elevating the tower
- Easier to install and maintain compared to alternatives
- Minimal modification of the existing tower & hardware
- Available in multi kV and design applications



Simulation Set-up: 3-φ Service Condition

- Tower modelled with a fully solid structure
- Conductors represented by straight cylindrical segments
- Adjacent circuit and shieldwires ignored (minimal effect)
- Detailed modelling of CICA and suspension fittings
- Refined meshing on points of interest (POI)
- Boundary conditions:

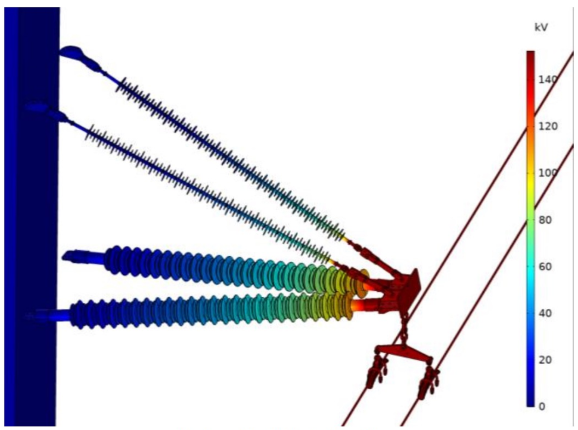
Component	Voltage (kV)
Studied phase	1.0*264/√3 (152kv)
Other phases	-0.5* 1.0*264/√3 (76kV)
Tower, CICA LV side hardware & ground plane	0



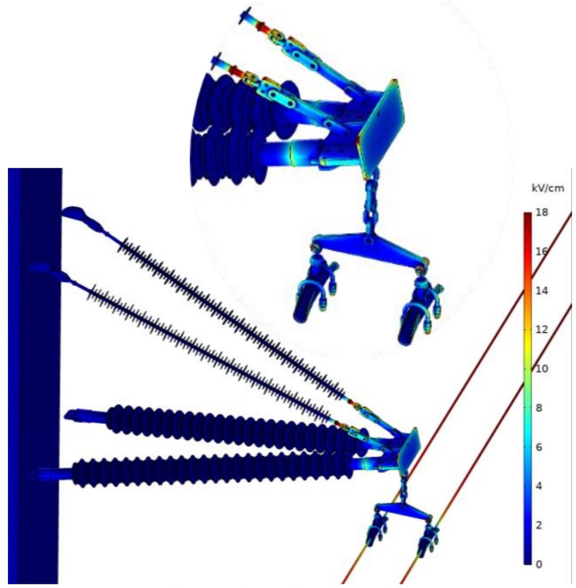
3-Phase Simulation (Service Condition)

Simulation Results without E-field Grading

Step One



Potential Distribution

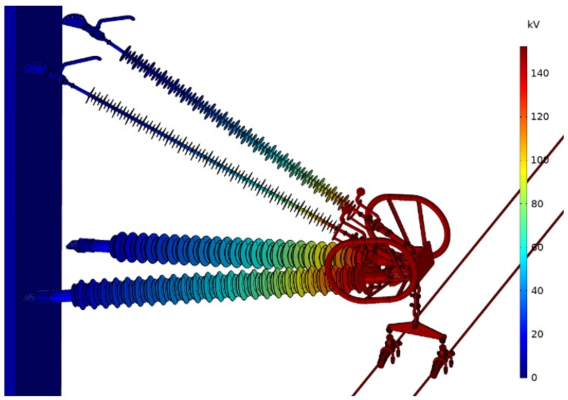


Electric Field Distribution

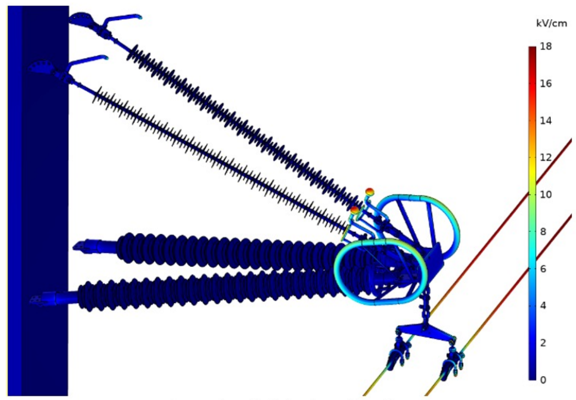
Potential	Point of Interest	Maximum Electric Field (kV/cm)
High Voltage	Suspension insulator housing	20.80
	Suspension insulator triple point	13.92
	Line post insulator housing	8.83
	Line post insulator triple point	11.02
	Node and hardware	32.18
	Conductor suspension fittings	23.96
Low Voltage	Suspension insulator housing	2.09
	Suspension insulator triple point	1.35
	Line post insulator housing	2.21
	Line post insulator triple point	2.49

Simulation Results with Optimized E-field Grading

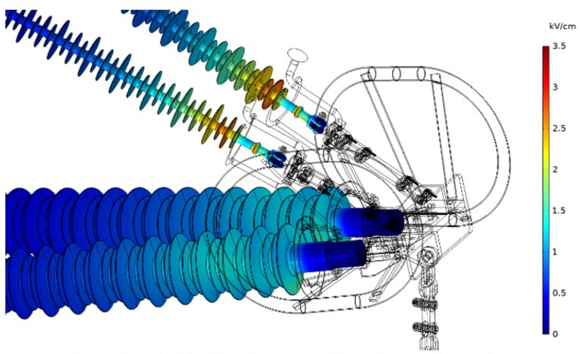
Step Two



Potential Distribution



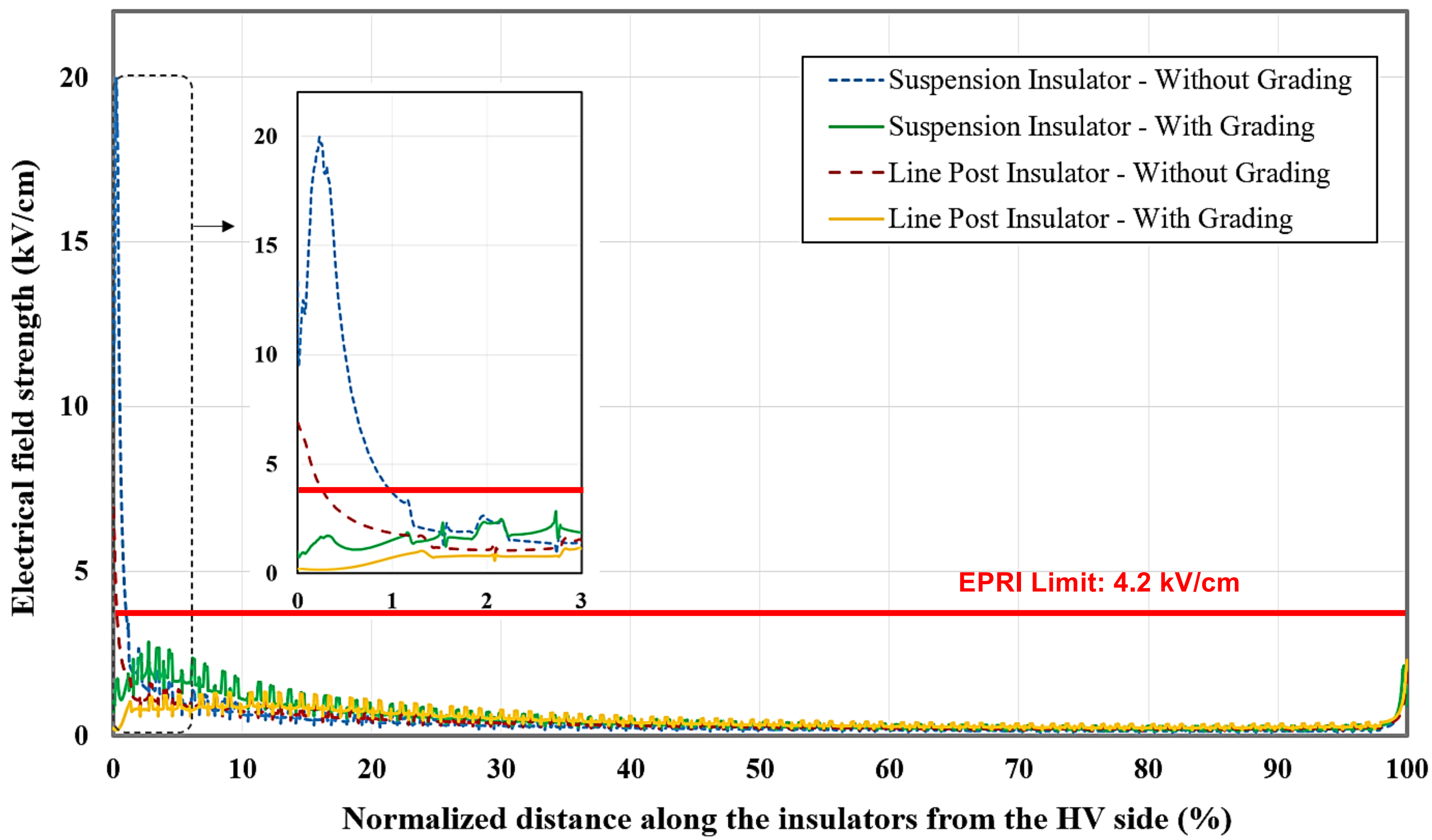
Electric Field Distribution



Electric Field Distribution (insulator housing)

Potential	Point of Interest	Maximum Electric Field (kV/cm)
High Voltage	Suspension insulator housing	3.23
	Suspension insulator triple point	1.45
	Line post insulator housing	1.74
	Line post insulator triple point	1.19
	Node and hardware	9.14
	Conductor suspension fittings	19.39
	Node shielding ring	10.62
	Line post insulator grading ring	4.70
	Suspension insulator arcing ring	16.05
Low Voltage	Suspension insulator housing	2.40
	Suspension insulator triple point	1.47
	Line post insulator housing	2.71
	Line post insulator triple point	2.73
	Suspension insulator arcing horn	6.34

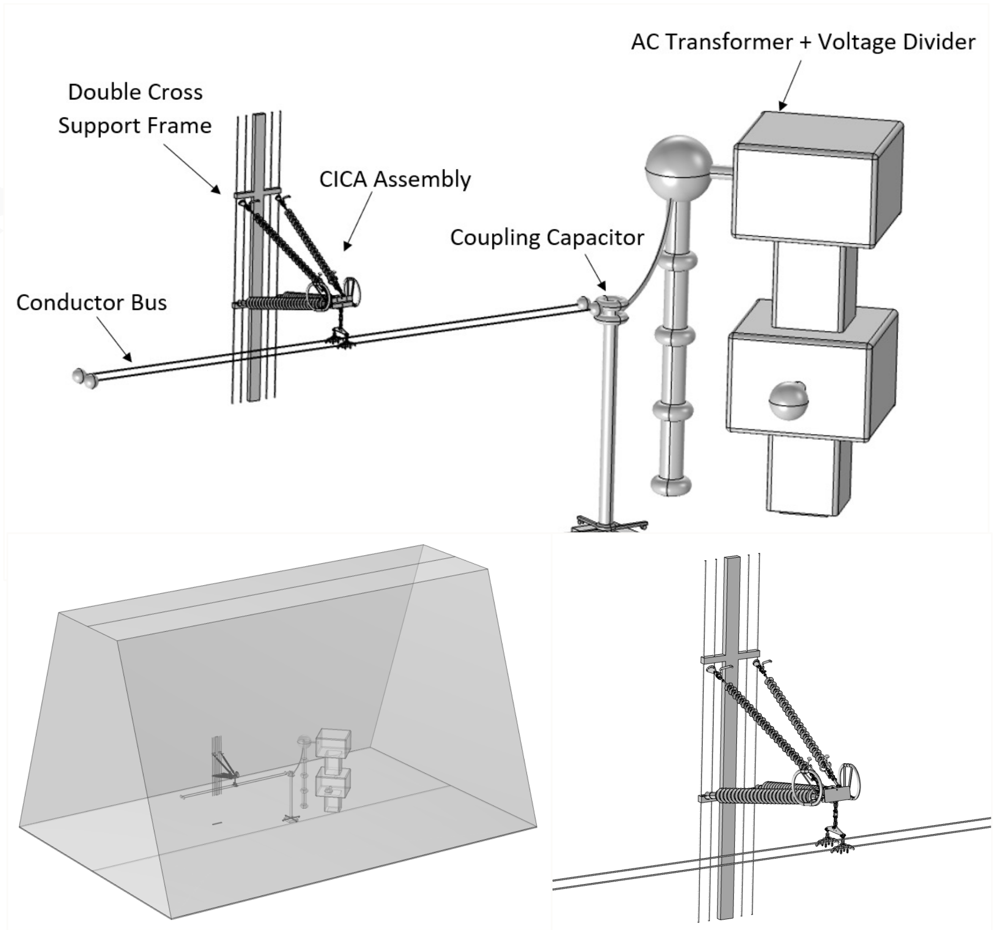
Results with Optimized E-field Grading



Comparison - Simulation vs Test floor results
Test Set-up: 1-φ Lab Test Condition

- Aim: To predict corona performance in laboratory conditions
- Laboratory mounting arrangement and environment modelled
- Boundary conditions:

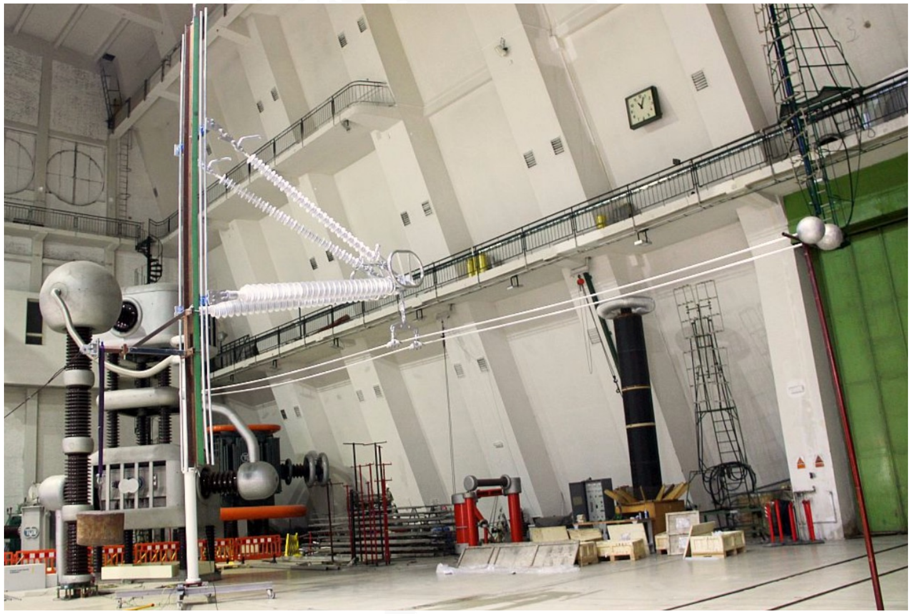
Component	Voltage (kV)
Studied phase	1.2*264/√3
Support structure, CICA LV side hardware & ground plane	0



1-Phase Simulation (Lab Test Condition)

Visible Corona and WDIC Test

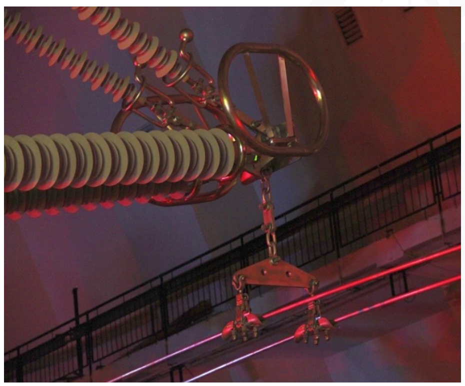
- Designed/mfg. full CICA assembly with suspension fittings and suspension clamps
- Conductor simulated by φ 22 mm aluminum tubes
- 457 mm bundle spacing, 12 m length and 4.05 m height above ground
- Tower body simulated by a 6 x 1 m ground plane
- Test set-up suspended by a roof crane and counter weight used to keep the assembly up-right



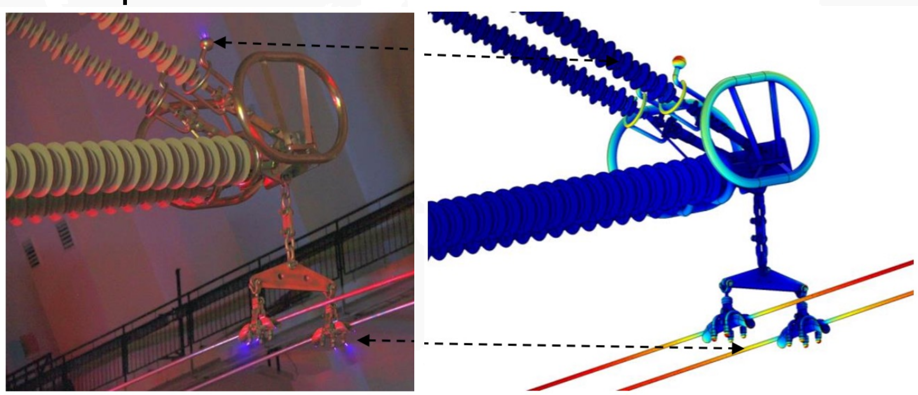
Test Set-up

Test Results

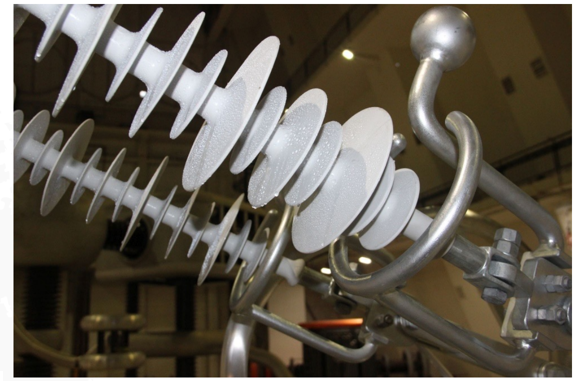
- No visible corona at specified test voltage of 220 kV ✓
- No WDIC at specified test voltage of 152 kV ✓
- Good correlation with FEA simulation ✓
- FEA predicted Corona inception at 300kV ✓

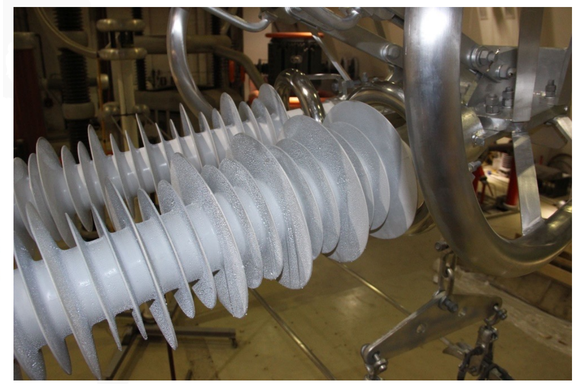


Test voltage: 220 kV
(no visible corona)



Test voltage: 300 kV
(visible corona pattern predicted by FEA)





Test voltage: 152 kV
(no WDIC)